

S/PRTS

10/524703  
[10191/4063]  
ST01 Rec'd PCT/PTO 16 FEB 2005

METHOD AND DEVICE FOR DETECTING THE OCCUPANCY STATE OF A SEAT

BACKGROUND INFORMATION

5 The present invention relates to a method for detecting the  
occupancy state of a seat, especially in a vehicle, and for  
use in activating means of restraint allocated to the seat, as  
a function of the occupancy state, in which, with the aid of  
an image recording system, a 3D image of the seat is recorded  
10 and evaluated with respect to the occupancy state, and  
possibly also with respect to the type of the occupancy, as  
well as a device for carrying out the method.

Means of restraint that are able to be activated irreversibly,  
especially pyrotechnically ignitable ones, such as air bags or  
15 belt pretensioners, have meanwhile become standard. When a  
situation is detected that is dangerous for a person sitting  
in the seat, especially an impact onto an obstacle, these  
means of restraint are triggered in order to protect the  
person from dangerous injury. For reasons of cost, the  
20 triggering should not occur if the seat is not occupied.  
Furthermore, triggering should not occur if there is not a  
person in the seat, but rather an object. Triggering is  
particularly to be avoided if the object is a baby carrier. In  
addition it would be desirable to be able to have triggering  
25 procedures that are adaptable as a function of the stature of  
the person. Therefore, in order to avoid very unsafe, only  
manually operable switches, a method and a device are required  
which, with the greatest possible safety, are able to detect,  
for one, the occupancy state as such. In addition, these  
30 methods and devices, under certain circumstances also together

with others, should permit distinguishing at least between objects and persons, and, if possible, also between different objects, and particularly between different persons or rather, types of persons.

5 For example, it is known from US 5,570,903 that one may assign a mat to the seat surface of a seat, with the aid of which the weight of an object acting on the seat is ascertainable. By using a matrix-like system of sensors, a pressure distribution may also be ascertained, and perhaps also the distance apart  
10 of the ischial tuberosities of a person. To be sure, the occupancy state is easy to ascertain, but this procedure is extraordinarily effortful, and also costly, since special seats are required.

From US 5,983,147 it is known that one may produce an image at  
15 least for the front passenger seat, using a stereo-video camera. The respective image may thereupon be evaluated as to whether the seat is occupied at all, and whether, if so, a person or an object is there. For the initialization of this procedure, a very effortful and drawn-out learning or training  
20 phase is required, since for each type of state to be detected, especially when objects and persons are to be distinguished, empirically determined training data have to be placed at disposal, and these training have first of all to be determined and entered. For the application of this, on the  
25 basis of the training data and data obtained by the image as well as appropriate algorithms, a classification is made, first according to occupancy state and then according to occupancy type. This procedure has grave disadvantages. For instance, types of occupancy that were not foreseen in the  
30 training data, are not able to be recorded, which may lead under certain circumstances to serious misinterpretations, that is, erroneous classifications. Moreover, changing illumination situations, of the kind frequently appearing in

daily traffic, may likewise lead to erroneous classifications. Also, in the training phase, non-trained seat parameters may lead to erroneous classifications. Finally, when a seat is exchanged, a renewed initialization has to be carried out, the  
5 corresponding training data not being available for all seats sold in the trade. Consequently, the known procedure based on the ascertainment of a 3D image is not only extremely costly, but is also unreliable in the wider scope.

Accordingly, the present invention is based on the object of  
10 improving the known aforementioned procedure to the extent that, in response to a smaller effort, greater safety may be achieved in detecting the occupancy state and possibly also the occupancy type.

#### Summary of the Invention

15 The object is attained by the method according to Claim 1 and by the device according to Claim 13. The present invention is further refined by the features of the dependent claims.

The basic idea of the present invention should be seen in that, as a reference for an unoccupied seat, a 3D pattern of  
20 the seat is set up, and, in any case for most seats, such 3D patterns are already available in the factory or in delivery, perhaps because the seat was developed with the aid of CAD technology, for instance, in the form of a so-called wire screen model. The 3D image ascertained in operation by the  
25 image recording system may now be analyzed, with respect to the 3D pattern, for at least serious and/or specific deviations. An effortful training phase is not required for the analysis. In further development, partial regions of the seat, such as the seat surface, the backrest, the headrest and  
30 also sections thereof, such as the upper section of the backrest and the lower section of the backrest may be analyzed with respect to the agreement of the 3D image with the 3D

pattern, so that, in the case of detecting an occupancy of the seat, certain classifications with respect to the type of the objects causing the occupancy may be carried out, and, as a matter of fact, completely iteratively.

## 5 Brief Description of the Drawings

The present invention is explained in greater detail with reference to the exemplary embodiments shown in the drawing, The figures show:

- 10      Fig. 1      the basic construction of a device for carrying out  
                the method according to the present invention, in a  
                side view of the seat,
- Fig. 2      a front view of seats in a vehicle,
- Fig. 3      schematically the various possibilities of motion of  
                the parts of the seat with respect to one another,
- 15      Fig. 4      a system in which separate image recording systems  
                are provided for front seats and rear seats,
- Fig. 5      the possibility of installing a single image  
                recording system for both front and rear seats,
- 20      Fig. 6      schematically, the basic appearance of a wire screen  
                model of a seat,
- Fig. 7      schematically, the basic construction of the  
                hierarchical evaluation possibility in the present  
                invention,
- 25      Fig. 8      schematically, a simple model of the hierarchical  
                construction usable for seats,
- Fig. 9      schematically, a flow chart for detecting the  
                occupancy state of a seat,

Fig. 10 schematically, a flow chart of a refinement in which the occupancy state is ascertained separately for certain partial regions.

#### Description of an Exemplary Embodiment

5 Figure 1 schematically shows a seat 1 having seat surface 2, backrest 3 and headrest 4 in a vehicle 5, namely a front passenger seat. In a front passenger seat 1, there is, for instance, a baby carrier 6 as the object occupying front passenger seat 1. In the area of dashboard 7 in vehicle 5,  
10 opposite front passenger seat 1 there is a pyrotechnically ignitable air bag 8 as example of a restraining means. A triggering unit 9 is allocated to air bag 8, which is able to be activated by an activating unit 10 for triggering or not triggering, as necessary according to a predefined type of  
15 triggering. For this purpose, activating unit 10 receives a series of input signals 11, of which at least one is a signal that reflects whether vehicle 5 is exposed to an acceleration corresponding to a dangerous impact upon an obstacle. In particular, activating unit 10 additionally receives an input  
20 signal 12 that describes the occupancy state of front passenger seat 1.

This occupancy state input signal 12 is generated in the given case by an evaluation circuit 13, activating unit 10 being able to activate triggering unit 9 only if occupancy state  
25 input signal 12 is present. That is to say, if front seat 1 is not occupied, triggering air bag 8 is prevented.

Evaluation circuit 13 makes the analysis, based, on the one hand, on a 3D pattern of front passenger seat 1, appropriate 3D pattern data 14 being stored in a possibly internal, but  
30 also an external memory (not shown in detail) and based, on the other hand, on 3D image data 15 which are ascertained by an image recording system 16. In the exemplary embodiment,

image recording system 16 is mounted in the vehicle's headliner 17, and is in a position to record front passenger seat 1 in its entirety, which is symbolized by a recording cone 18 shown by broken lines.

5 Expediently, image recording system 16 has two video cameras 19 and 20, as shown in Figure 2, in order to be able, in a convenient manner, to record a 3D image and generate from it corresponding data 15. Figure 2 also shows that, using image recording system 16, not only front passenger seat 1 but also  
10 driver's seat 21 may be recorded. However, the desired avoidance, in order to avoid unnecessary repair costs, of the irreversibly activatable triggering of the means of restraint allocated to driver's seat 21 in the case of non-occupancy of driver's seat 21 is of rather subordinate importance, since,  
15 for a traveling vehicle, one may basically assume an occupancy state (to be sure, even by one person). However, a classification of the occupancy type may be meaningful for triggering.

However, all the data describing the real situation of a seat  
20 are usable with 3D image data 15 in the sense of the present invention. They may be ascertained by any per se distance measuring sensors, based on which an image in a spatial coordinate system is possible. The following, for example, are suitable: Stereo camera systems, multi-camera systems  
25 (made up of at least two cameras), so-called range image systems, that analyze according to an operating time principle, laser scanners, radar systems, sensors that work with structured illumination, etc. Expediently, there are systems being used anyway in vehicle 5 that is being examined.

30 Figure 1 also shows that evaluation circuit 13 is able to supply additional signals, namely type occupancy input signals 22, to activating unit 10 if evaluation circuit 13 is designed



in an appropriate manner, as will be described below in greater detail.

Even though the present invention is being explained in the light of the activation of an air bag 8 allocated to front passenger seat 1 as a means of restraint that is irreversibly  
5 activatable, it has been shown that the present invention may be used basically for all means of restraint allocated to a seat, for whose activation the occupancy state of the seat and possibly also the type of occupancy of the seat are being  
10 utilized, such as pyrotechnically ignitable belt tensioners, seat belt tensioners activated by an electric motor, side air bag, knee air bag, head air bag, adjusting mechanisms for bringing the parts of the seat (seat surface, backrest, headrest) into a favorable situation for the impact that is to  
15 be expected. Anyhow, to the extent that the occupancy type is detected, which will be explained in more detail below, the present invention is basically also usable for activating means of restraint for the driver's seat 21.

As is explained in greater detail below, using the present  
20 invention, not only is one able to generate in a favorable manner occupancy state input signal 12, that indicates the occupancy state, for activating unit 10, but also at least one input signal 22 that specifies and discriminates with respect to the type of occupancy. This means that, with the aid of  
25 occupancy state input signal 12, it is only recorded whether seat 1 is occupied, which may include an object such as baby carrier 6. Since, however, air bag 8 is not to be triggered in response to objects such as baby carriers 6, expediently upon detection of an occupied seat 1 one should undertake  
30 additional discriminations to determine whether seat 1 is occupied by a person or an object.

This discrimination may take place in a method known per se, using the usual signals within the scope of input signals 11. As is explained in greater detail below, this discrimination is also able to take place with the aid of the present invention, and with the aid of generating the at least one occupancy type input signal 22.

A one-time state may be erroneous, so that it is extremely expedient to verify a once ascertained evaluation result at a temporal distance, especially since a change of the occupancy state and a change of the occupancy type during travel are made only rarely, and possibly at considerable time spans, whereas the ascertainment of the 3D image data ("scanning"), by contrast, is repeated at substantially smaller time periods. Evaluation circuit 13 expediently carries out a temporal filtering of evaluating results obtained one after another by, for example, forming a moving average value or a median value or the like. Thereby signals 12 and 22 may be designed to be very robust, i.e. very secure in their interpretational content.

In a similar representation as in Figure 1, Figure 3 shows first of all to what extent the various partial regions of seat 1, seat surface 2, backrest 3, headrest 4 may be adjustable to one another or against one another, as well as being adjustable with respect to vehicle 5. With the aid of image recording system 16, the 3D image will correspond to the actual position of the various partial regions 2, 3, 4 of seat 1, and, to be sure, for example, in coordinate directions x, y and z. In any case, upon suitable preparation of data 14 of the 3D pattern, that corresponds to the mutual allocation of these partial regions, on the one hand, one may carry out an analysis of 3D image data 15 for discriminating with respect to the deviation of the actual position of the various partial regions from a desired position. On the other hand, what is



avoided is an erroneous interpretation as the presence of an occupancy state, or even as the non-presence of an occupancy state. Finally, for each of the partial regions, by separate evaluation and drawing upon the appropriate data of the pattern for the various partial regions, seat surface 2, backrest 3 and headrest 4, one may separately determine a respective occupancy state, from which, for the purpose of classification, one may draw a conclusion on the certain type of the occupancy. If, for example, seat surface 2 and backrest 3 are detected as being occupied, but headrest 3 is detected as being not occupied, this may be interpreted as the presence of occupancy of seat 1 by an object or a small person. In a hierarchical further development, in the various partial regions one may, in turn, define subregions which are supplied to an evaluation with respect to corresponding subregions in the pattern, and, for example, the presence of an occupancy state in the lower section of backrest 3, and the non-presence of an occupancy state in the upper section of backrest 3 may be interpreted as the presence of an object, such as perhaps a baby carrier 6, and this may be drawn upon to avoid triggering of the irreversible means of restraint, in spite of the ascertained occupancy state of seat 1.

Figure 4 shows schematically that the present invention may be used even for back seats 23. For this purpose, in the specific embodiment according to Figure 4, a separate image recording system 24 is provided for back seats 23. Alternatively, as shown in Figure 5, a common image recording system 25 may be provided for both front passenger seat 1 in the front region of vehicle 5 and for back seats 23. Without this requiring a more detailed explanation, the present invention may also be used in vehicles 5 that have more than two rows of seats, and/or in which more than two seats are situated next to one another. This means that the present

invention may be used in every case in which, as a function of the occupancy state of a seat, and possibly of the type of occupancy of the seat, devices allocated to the seat are to be triggered, are to be triggered in a certain way and/or are to  
5 be prevented from being triggered.

Image recording systems 16, 24 and/or 26 may also be provided at other locations in vehicle 5, for instance, at the vehicle console, the A-pillar, B-pillar and/or the C-pillar, etc. What is essential is that the recording of 3D image data 15 of  
10 an observed seat 1, 21, 23 is as unobstructed or unobstructable as possible.

An example of how the data with respect to the pattern of a seat are able to be developed is seen in Figure 6. Figure 6 shows, schematically in a 3-dimensional coordinate system, a  
15 so-called wire screen model 30 for a seat having a seat surface 36 and a backrest 37. Beadings 32 that edge seat wells 31, and beadings 34 that edge back well 33 at the side, as well as the less prominently shaped upper beading 35 are clearly recognizable. It is also clearly recognizable that  
20 the region of seat surface 36 and the region of backrest 37 of this wire screen model 30 of a seat are easily separable from one another and thereby may be discriminated from one another. Such a wire screen model 30 of a seat is generated as early as by the manufacturer, in usual manufacturing processes, during  
25 development and using CAD, so that so that the corresponding data may be supplied along with the delivery of the seat, so that 3D pattern data 14 (Fig.1) do not have to be generated separately. This applies basically also to retrofitted special models of seats, to the extent that these in a certain  
30 series by the respective manufacturer.

It has been shown that, using little effort, subregions of the kind mentioned, such as the lower section of the backrest and

the upper section of the backrest may be separated from each other, and thereby drawn upon for an evaluation according to the present invention.

If, as in the exemplary embodiment, the 3D image of a seat is recorded with the aid of a video image recording system, the corresponding 3D image data 15 are available in a different format than the 3D pattern data 14, if these, for instance, were generated starting from a wire screen model 30. It is then necessary to carry out a format transformation in such a way that evaluation circuit 13 is able to draw upon data having the same data format for the evaluation.

Within the scope of the present invention, it is also possible to generate 3D pattern data 14 themselves in an initializing step, and this is done in that seat 1 is recorded, using image recording system 16 of vehicle 5, if seat 1 is guaranteed to be unoccupied, that possibly the data ascertained here are submitted to an abstraction, and these are then filed as the 3D pattern data 14 in a memory for evaluation circuit 13, i.e. they are input. Expediently, such a recording or scanning takes place under specified surrounding conditions, that is, before delivery of vehicle 5. In the case of new installation of a seat, this initialization would, if necessary, have to be carried out over again.

In the light of Figure 7, the model-based method according to the present invention is explained in general according to the basic principle.

A pattern of zeroth order 42 corresponding to a pattern of a seat 1, which is represented by a large circle, has a predefined positional relationship 41 to vehicle 5 in which seat 1 is installed. Pattern of zeroth order 42 includes several patterns of first order 44, which as a totality have a certain positional relationship 43 with respect to pattern of

the zeroth order 42. Patterns of first order 44 have among themselves, in turn, a predefined positional relationship 45. Patterns of first order 44 again include several patterns of second order 46 which, in their totality, have a predefined positional relationship 49 with respect to pattern of first order 44, and which, in turn, have a predefined positional relationship 47 with respect to one another. Second-order pattern 46, in turn, may have third-order patterns 48, etc, as was indicated. Thus, a strongly hierarchical classification is possible in this area.

For a seat 1 not having a headrest 4, let us state this more precisely in the light of Figure 8. Pattern 51 of seat 1, again represented by a circle, has a predefined positional relationship 50 to vehicle 5. The pattern of the backrest as a first-order pattern and pattern 55 of the seat surface, also as a first-order pattern, on the one hand have a predefined positional relationship 54 to each other. Furthermore, pattern 53 of the backrest has a certain positional relationship 52 to pattern 51, pattern 55 of the seat surface also having a certain positional relationship 56 to pattern 51 of the overall seat.

This hierarchical structure makes it permissible, when applying the method according to the present invention, to end the evaluation as a function of the result of the evaluation with respect to a pattern of a lower order, perhaps when it has been determined that the seat is not occupied, or to cause additional evaluations with respect to patterns of a higher order to be carried out, and if necessary, selected ones of these, perhaps for ascertaining whether for seats, determined as being occupied, the occupancy is by an object or a person, etc.

The procedure according to the present invention is next explained in the light of the flow chart as in Figure 9. As was mentioned before, evaluation circuit 13, on the one hand, receives 3D pattern data 14 from a memory, for instance, data  
5 corresponding to wire screen model 30, as well as 3D image data 15, for example, data ascertained from an image recording system 16, or even 3D image data ascertained by any other vehicle-resident measuring system, which are in a position of reproducing the actual state. As was mentioned, these data 14  
10 and 15 are generally not present in the same data format. In a step S1 there first takes place a hierarchical adaptation of 3D pattern data 14 and 3D image data 15. In order clearly to fix the extent of the necessary adaptation, it is first required that one specify a criterion 26, based on which the  
15 evaluation is to take place, for instance, the evaluation may be made based on the sum of the squares of the deviations. This criterion 26, in one step S11, fixes the type and the volume of the necessary transformation and also the abstraction. In a step S12 there then follows the  
20 transformation, namely, in the exemplary embodiment, a transformation of the 3D pattern data into the format of the 3D image data. Of course, a transformation of the 3D image data into the format of the 3D pattern data may also be carried out, or one may also carry out a transformation both  
25 of the 3D pattern data and the 3D image data into a third data format. As a function of criterion 26, the measure of a necessary or meaningful abstraction of the data for the purpose of evaluation may also be determined. Starting from the data now present in the same data format, in step S13  
30 there takes place the determination as to whether there are deviations between the 3D pattern data and the 3D image data, and if necessary, in what volume, or to what extent.



In a step S2 there is then made the determination as to whether the determined deviations exceed a fixed threshold 27 or not. If the determined deviations are less than threshold 27, this is interpreted as meaning that corresponding seat 1 is empty, i.e. not occupied (Step S3). If the deviation determined in step S2 exceeds threshold 27, this is interpreted as meaning that the seat is occupied (step 4). Output signal 12 of evaluation circuit 13 reflects the one or the other state.

10 The fixing of threshold 27 is required if for no other reason than that, based on measuring inaccuracies and conversion inaccuracies in the transformation, the determination of deviations may come about, although actually there are none. Threshold 27 may also be fixed in such a way that putting down  
15 small objects onto the seat is not detected as being an occupation of the seat, something like laying down magazines or articles of clothing. On the other hand, threshold 27 is expediently determined so that when larger objects are laid down, the assumption is made that there is an occupancy state.  
20 In this context, the value of relevant threshold 27 for front seats and rear seats may be quite different (in case of an accident, a briefcase left on the rear seat may represent a dangerous missile for people on the front seats).

Step S5 simulates continuing method steps which are provided  
25 for generating signals 22 that designate the type of occupancy, in the sense of a hierarchical application of the basic idea of the present invention. Let us now explain this schematically in the light of the flow diagram as in Figure 10.

30 In the case in which in step S4 the occupancy of the seat has been determined, in step S6 there is first carried out a selection with respect to the partial regions to be examined



(seat surface, backrest, headrest) or even subregions thereof, such as lower section and upper section of the backrest, corresponding to step S61.

If necessary, a renewed transformation or adaptation has to be  
5 made in the sense of step S1 and its substeps S11 and S12.  
Now, in step S63, the deviation determined for the partial region or the subregion is compared to an appropriate threshold, and, in the case at hand, corresponding to step S64 or corresponding to step S65 it is determined whether the  
10 partial region of the seat or the subregion of the partial region of the seat may be regarded as being occupied or as not being occupied or empty. This may be done stepwise or in parallel for various partial regions and subregions of partial regions. Taking up the example of baby carrier 6 according to  
15 Figure 1, it is first determined, by using the procedure according to the flow diagram as in Figure 9, whether seat 1 is occupied at all. If yes, partial regions, seat surface 2, backrest 3, headrest 4, are first investigated with respect to occupancy, it being determined, for the example of baby  
20 carrier 6, that seat surface 6 is to be regarded as being occupied, and that headrest 4 is to be regarded as being empty, it being assumed that backrest 3 is also to be regarded as occupied because of the exceeding of a threshold. In this case it is expedient and meaningful to investigate subregions  
25 of backrest 3 as to whether they have to be regarded as occupied or not. In this corresponding evaluation it will be determined that the upper section of backrest 3 should be regarded as unoccupied, while the lower section of the backrest is to be regarded as occupied. In a similar manner  
30 one may discriminate, for instance, with respect to whether a child's seat is present.

Such determinations may be drawn upon for the classification of the object in the seat.

The separation or segmentation undertaken in step S61 may also be drawn upon object-related, i.e. image-related in a manner known per se, in a step S7 for calculating object features in a step S71 and corresponding classification in a step S72.

5 Hereby, in a manner known per se, one is able to calculate the surface occupied by an object and the like, that is, criteria which make classification possible in the usual way, this classification making possible the reaction, that is, the  
10 suitable generation of activating signals in activating unit 10 for triggering unit 9.

In summary, the present invention first of all permits the recording of the occupancy state in a simple manner, and, building up on the same basic idea, also assessing or rather classifying the type of occupancy of a seat.